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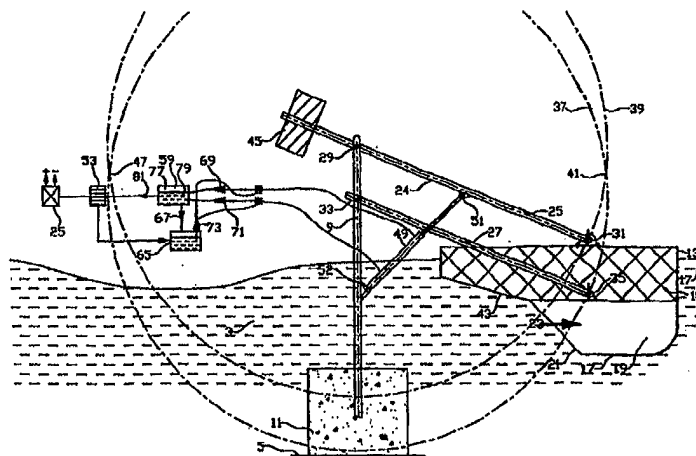
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(54) Title: SYSTEM FOR CONVERSION OF WAVE ENERGY



(57) Abstract

A system for conversion of wave energy in a body of water having a floor, comprising a stationary element (9) rigidly mounted to the floor of the body of water, buoyancy means (13), coupling means for hingedly connecting the buoyancy means to the stationary element wherein the buoyancy means is pivotal in a vertical plane about a central axis in the stationary element (9), at least one piston means (49) for compressing and drawing hydraulic fluid when the piston means is contracted or extended, correspondingly, the piston means being hinged at one end to the stationary element or the floor and hinged at its other end to the buoyancy means or the coupling means, a hydraulic motor (53) mechanically coupled to an electric generator or to any other applicable device, and a piping system (57) coupling the hydraulic fluid in the piston means to the hydraulic motor.

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SYSTEM FOR CONVERSION OF WAVE ENERGY

TECHNICAL FIELD

The present invention relates to the utilization of energy from sea waves and currents and particularly to apparatus for converting sea wave and current energy to consumable energy.

BACKGROUND ART

The utilization of the energy produced by the ebb and flow of sea waves has been the subject of numerous and varied proposals. Apparatus has been proposed, comprising machines which float or are fixed to the sea floor and which convert the wave energy into storable form or the use of floating buoys or bladders which oscillate vertically, in step with forces produced by the waves.

Floating members are usually suggested in some devices for the exploitation of the gravitational forces induced by the rise and fall of the waves, while static structures are suggested in other devices for the conversion of the horizontal flow of water into electricity. Therefore, each such device resort to exploiting only one form of energy that may be produced by the ebb and flow of waves and currents.

Attempts to convert the wave force, generated by the rise and fall of the flotation bladders, to electric energy have been made using the rotation force of gears to activate a hydraulic pump. The gears are connected to the flotation bladders and to a hydraulic pump that discharges fluid into an accumulator which then delivers fluid to an electric generating station.

One disadvantage of such apparatus that relies on floating members is that the amount of sea wave energy absorbed by the member is dependent on the location of the member in relation to the tide level that may vary as much as several meters between the low tide and the high tide. Furthermore, some devices include elements that either must be installed on the ocean floor or on the shore or on a platform, and therefore are extremely expensive to manufacture or to maintain or are confined to shallow waters or must be proximate to the sea shore.

Various solutions have been suggested including the use of wave transducers connected to computers in order to accurately control the movement of the floating members. These solutions have the disadvantage of requiring sophisticated electronic equipment which is subject to breakdown, inefficient and costly to install and maintain. Apparatus which is situated away from the shore requires expensive equipment in order to convert the wave energy and transfer it to the shore.

There is thus a widely recognized need for, and it would be highly advantageous to have an efficient and inexpensive method of converting the energy produced by sea waves into consumable energy, such as electricity, while overcoming the above mentioned drawbacks.

These and other objectives are provided by the invention described below.

DISCLOSURE OF INVENTION

According to the present invention there is thus provided a system for conversion of wave energy in a body of water having a floor, comprising a stationary element rigidly mounted to the floor of the body of water, buoyancy means, coupling means for hingedly connecting the buoyancy means to the stationary element wherein the buoyancy means is pivotal in a vertical plane about a central axis in the stationary element, at least one piston means for compressing and drawing hydraulic fluid when the piston means is contracted or extended, correspondingly, the piston means being hinged at one end to the stationary element or the floor and hinged at its other end to the buoyancy means or the coupling means, a hydraulic motor mechanically coupled to an electric generator or to any other applicable device, and a piping system coupling the hydraulic fluid in the piston means to the hydraulic motor.

In a preferred embodiment the buoyancy means comprises a buoy portion and a wave energy collecting means, the collecting means comprising a cavity having an opening facing the direction of advancement of oncoming waves. Preferably, the coupling means comprise at least two parallel support arms, each of which is hinged to the stationary element and to the buoyancy means, wherein each support arm is pivotal in a vertical plane about the stationary element and the buoyancy means, the corresponding length of each support arm between its hinges is equal in all corresponding support arms, and wherein the buoyancy means is free to move along a circle, or a fraction of a circle, in a vertical plane in respect of the stationary element while the buoy portion is retained above the collecting means. Further preferably, the opening is sloped so that its upper edge is closer to the oncoming waves than its lower edge, and the buoyancy means comprise a wave diversion surface extending above the opening toward the oncoming waves.

Optionally, at least one of the support arms comprises a balancing weight extending from the central axis toward the side opposed to the buoyancy means.

According to another aspect of a preferred embodiment, the piping system comprises a pressure tank, and the piping system couples the hydraulic fluid in the piston means to the pressure tank and the pressure tank to the hydraulic motor.

Preferably, the piping system comprises two conduits leading hydraulic fluid from the at least one piston means to the pressure tank, which conduit comprise a first conduit for leading hydraulic fluid into the pressure tank when the piston means is contracted, and a second conduit for leading hydraulic fluid into the pressure tank when the piston means is extended.

Further preferably, the piping system further comprises a hydraulic fluid reserve tank for supplying hydraulic fluid to the piston means, and collecting hydraulic fluid from the hydraulic motor and excess hydraulic fluid from the pressure tank.

The piping system may further comprise a plurality of one-way pressure relief or pressure difference control valves for confining the flow of the hydraulic fluid to the desired directions, and the pressure tank and/or the hydraulic motor may be fitted with pressure relief valves for draining excess fluid from the system.

Preferably, the pressure tank contains gas, the gas being compressed in high pressure for substantially rendering unruffled the pressure applied from the pressure tank to the hydraulic motor.

Further features and advantages of the invention will be apparent from the description below, given by way of example only.

BRIEF DESCRIPTION OF THE DRAWING

The present invention will be further understood and appreciated from the following detailed description, taken in conjunction with the following enclosed drawing denoted Figure 1 which illustrates in a schematic diagram the proposed system for conversion of wave energy to consumable power according to a preferred embodiment of the present invention

BEST MODES FOR CARRYING OUT THE INVENTION

Referring to Figure 1, there are schematically shown the main components of the wave energy conversion system, generally denoted 1. System 1 may be theoretically installed in any body of water 3 having a floor 5 and a water level 7. However, system 1 is primarily directed at exploiting large waves that naturally appear in oceans, seas and large lakes. System 1 comprises a stationary element 9 rigidly mounted to floor 5, such as by means of a concrete mass 11. It will be appreciated that the proportions of all the elements of system 1 in general, and of stationary element 9 in particular are exaggerated for the sake of demonstration and may vary with tremendous differences. For example, the height and width of stationary element 9 may be much larger if system 1 is installed in high seas or where the ocean floor is deep. System 1 captures the wave energy by buoyancy means 13 that are designed to float on the water. Preferably, buoyancy means 13 comprise a buoy portion 15 and a wave energy collecting means 17. Collecting means 17 comprise a cavity 19 having an opening 21 facing the direction of advancement of oncoming waves designated as arrow 23.

Buoyancy means 13 are hinged to stationary element 9 by means of a coupling means 24 - which may be as simple as a plain rod, wherein buoyancy means 13 is pivotal in a vertical plane about an axis in stationary element 9.

The preferred embodiment in Figure 1 demonstrates a more complex coupling means 24. Coupling means 24 comprises at least two parallel support arms, such as support arms 25 and 27, each of which is hinged to stationary element 9 and to buoyancy means 13. Support arm 25 is hinged to stationary element 9 at hinge 29 and to buoyancy means 13 at hinge 31. Support arm 27 is hinged to stationary element 9 at hinge 23 and to buoyancy means 13 at hinge 35. Each support arm is pivotal in a vertical plane about its hinges in stationary element 9 and buoyancy means 13. The length of each support arm between its hinges is equal in all corresponding support arms. Accordingly, a virtual parallelogram is always defined by the four hinges of each pair of such support arms, such as by axes 29, 31, 33 and 35. It is clear from the above description that if all the support arms, such as arms 25 and 27, are allowed to move without further constraints, their hinges at the to buoyancy means 13, namely - 31 and 35, each move along a circular track, 37 and 39, respectively. Thus, buoyancy means 13 is free to move along a circle (which is centered at halfway between axes 29 and 31), or a fraction of such circle, in a vertical plane in respect of stationary element 9, while buoy portion 15 is retained above collecting means 17. The bearing between buoyancy means 13 and the support arms may be designed so as to limit the movement of the support arms in respect of stationary element 9 and therefore to limit the movement of buoyancy means 13 to a fraction of a circular track. Considerations such as structural strength and the ratio between the average wave height and the circular radius may be taken into account for the specific design of a system 1.

When a wave encounters buoyancy means 13, buoyancy means 13 floats and rises upwards due to its lighter intrinsic weight. Its lower collecting means 19 is either already immersed in the water or fills up with the wave water penetrating cavity 19 through opening 21. After the wave passes system 1, the water level there about falls sharply and at this stage the extra weight of the water contained in cavity 19 build up a substantial gravitational force that pulls down buoyancy means 13 with extended force.

Moreover, the power of a wave that hits buoyancy means 13 in direction 23 may be divided into two vector forces at right angles: a vertically rising vector force and a horizontal forces in direction 23. In the position between side 41 of the circular path of buoyancy means 13 and the bottom of this path (closer to stationary element 9), both vector forces contribute to the lifting force of buoyancy means 13 toward side 41 while filling cavity 19 with water and add to the potential gravitational energy accumulated in cavity 19. This extra energy is released when the wave passes as explained above. In order to enhance the energy absorption of buoyancy means 13 in such configuration, its wall 43 facing the oncoming waves may be sloped so as to form a wave diversion surface extending above opening 21 toward the oncoming waves, as in Figure 1. Opening 21 may be sloped as well so that its upper edge is closer to the oncoming waves than its lower edge, as in Figure 1. Such structure of opening 21 also contributes to absorption of more accumulated water in cavity 19 when a wave hits buoyancy means 13 and to release of more water when the wave is gone.

Optionally, at least one of the support arms, such as arm 25 in Figure 1, may comprises a balancing weight 45 extending from central axis 29 toward the side opposed to buoyancy means 23.

It will be appreciated that since buoyancy means 13 moves along a circular path that the rise and fall of the waves contribute more to the vertical vector force, that moves means 13, in the vicinity of sides 41 and 47 of the circular path rather than the top or bottom thereof. Accordingly, system 1 may be designed so as to locate buoyancy means 13 most of the time in the vicinity of sides 41 or 47 of its circular path in a wavy water body, or closer to the bottom or top vicinity, in a water body where changing undercurrents are dominant.

In addition, in cases where waves tend to change their oncoming direction 23, system 1 may be easily adapted to change its orientation so as to face the right direction of the oncoming waves. This may be accomplished, for instance, by rendering stationary element 9 or its upper portion freely movable about an axis there along, with a "pointed" hydrodynamic shaping of buoyancy means 13 (and even weight 45) - resembling weather vanes.

In order to convert the wave energy in to consumable energy, system 1 comprises at least one piston means, such as piston means 49 for compressing and drawing hydraulic fluid when the piston means is contracted or extended, correspondingly. Piston means 49 is hinged at one end - such as at hinge 51 in Figure 1, to one of the support arms, namely - arm 25 in Figure 1, in location remote from hinge 29 or directly to buoyancy means 13. Piston means 49 is hinged at its other end to stationary element 9 - such as at hinge 52 in Figure 1, or directly to floor 5. System 1 further comprises a hydraulic motor 53 mechanically coupled to an electric generator or to any other applicable device. Finally, system 1 comprises a piping system 57 coupling hydraulic fluid in piston means 49 to hydraulic motor 53.

As an optional feature, piping system 57 may comprise a pressure tank 59. In such a case piping system 57 couples the hydraulic fluid in piston means 49 to pressure tank 59 and pressure tank 59 to hydraulic motor 53.

In a preferable embodiment, piping system 57 comprises two conduits - 61 and 63, leading hydraulic fluid from piston means 49 to pressure tank 59. Piping system 57 comprise a first conduit 61 for leading hydraulic fluid into pressure tank 59 when piston means 49 is contracted, and a second conduit 63 for leading hydraulic fluid into pressure tank 59 when piston means 49 is extended.

Piping system 57 may provide a simple closed circuit that directly communicates piston means 49 to hydraulic motor 53. However, piping system 57 preferably comprises a hydraulic fluid reserve tank 65 for supplying hydraulic fluid to piston means 49, and collecting hydraulic fluid from hydraulic motor 53. In case wherein pressure tank 59 form part of piping system 57, hydraulic fluid reserve tank 65 serves to supply hydraulic fluid to piston means 49 and to collect hydraulic fluid from hydraulic motor 53 and excess hydraulic fluid from pressure tank 59.

Preferably, piping system 57 further comprises a plurality of one-way pressure relief or pressure difference control valves for confining the flow of hydraulic fluid to the desired directions. For example, hydraulic fluid pressure tank 59 may be fitted with pressure relief valves 67 for draining excess fluid from tank 59. One possible arrangement of one way valves is shown in Figure 1. Valves 69 and 71 are mounted on conduits 61 and 63, respectively, and allow one way flow only toward pressure tank 59 (or hydraulic motor 53 - if directly fed by conduits 61 and 63). Valve 73 allow one way flow only - toward conduits 61 and 63 - when piston means 49 exerts a suction force on either of these conduits. Equivalent arrangements, including such that

comprise valves that are mechanically or electronically coupled or controlled may be employed for similar purposes.

Pressure tank 59 is an intermediate device used for regulating the abrupt pressures produced by piston means 49 - due to troubled or stormy temper of the waves and the resulting abrupt motions of buoyant means 13. Pressure tank 59 contains gas 77 in high pressure, such as hundreds of Atmospheres, and a reservoir 79 of hydraulic fluid. The pressure in pressure tank 59 builds up as piston means 49 feeds more and more hydraulic fluid into pressure tank 59. The gas, which is preferably "inert" in respect of the hydraulic fluid, relaxes the pressure applied from pressure tank 59 to hydraulic motor 53 and renders it unruffled. If hydraulic oil is used as the hydraulic fluid, Nitrogen may be used as a substantially inexpensive gas which is inactive with the hydraulic fluid. A valve 81 allows one way flow of hydraulic fluid from pressure tank 59 to hydraulic motor 53 - when the pressure in pressure tank 59 builds up to reach a predetermined level or when valve 81 is opened by an external controls.

It will be appreciated by those skilled in the art that the invention is not limited to what has been shown and described hereinabove by way of example only. Rather, the invention is limited solely by the claims which follow.

CLAIMS

1. A system for conversion of wave energy in a body of water having a floor, comprising:

- (a) a stationary element rigidly mounted to the floor of the body of water;
- (b) buoyancy means;
- (c) coupling means for hingedly connecting said buoyancy means to said stationary element wherein said buoyancy means is pivotal in a vertical plane about a central axis in said stationary element;
- (d) at least one piston means for compressing and drawing hydraulic fluid when said piston means is contracted or extended, correspondingly, said piston means being hinged at one end to said stationary element or said floor and hinged at its other end to said buoyancy means or said coupling means;
- (e) a hydraulic motor mechanically coupled to an electric generator or to any other applicable device; and
- (f) a piping system coupling said hydraulic fluid in said piston means to said hydraulic motor.

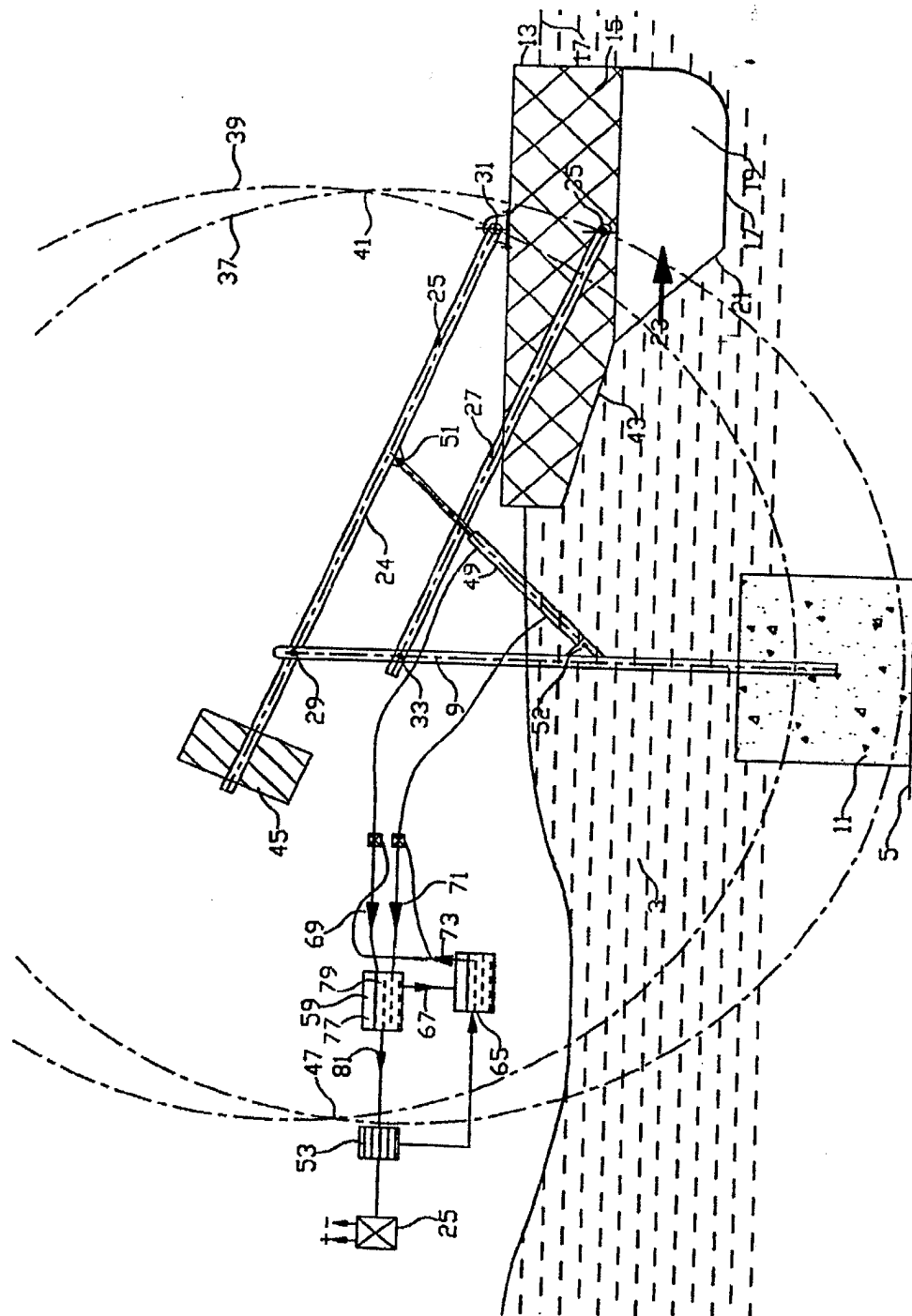
2. The system as claimed in claim 1, wherein said buoyancy means comprises a buoy portion and a wave energy collecting means, the collecting means comprising a cavity having an opening facing the direction of advancement of oncoming waves.

3. The system as claimed in claim 2, wherein said coupling means comprise at least two parallel support arms, each of which is hinged to said stationary element and to said buoyancy means, wherein each support arm is pivotal in a vertical plane about said stationary element and said buoyancy means, the corresponding length of each support arm between its hinges is equal in all corresponding support arms, and

wherein said buoyancy means is free to move along a circle, or a fraction of a circle, in a vertical plane in respect of said stationary element while said buoy portion is retained above said collecting means.

4. The system as claimed in claim 1, wherein said opening is sloped so that its upper edge is closer to said oncoming waves than its lower edge.
5. The system as claimed in claim 2, wherein said buoyancy means comprise a wave diversion surface extending above said opening toward said oncoming waves.
6. The system as claimed in claim 3, wherein at least one of said support arms comprises a balancing weight extending from said central axis toward the side opposed to said buoyancy means.
7. The system as claimed in claim 1, wherein said piping system comprises a pressure tank, and said piping system couples said hydraulic fluid in said piston means to said pressure tank and said pressure tank to said hydraulic motor.
8. The system as claimed in claim 1, wherein said piping system comprises two conduits leading hydraulic fluid from said at least one piston means to said pressure tank, which conduit comprise a first conduit for leading hydraulic fluid into said pressure tank when said piston means is contracted, and a second conduit for leading hydraulic fluid into said pressure tank when said piston means is extended.
9. The system as claimed in claim 1, wherein said piping system further comprises a hydraulic fluid reserve tank for supplying hydraulic fluid to said piston means, and collecting hydraulic fluid from said hydraulic motor.

10. The system as claimed in claim 7, wherein said piping system further comprises a hydraulic fluid reserve tank for supplying hydraulic fluid to said piston means, and collecting hydraulic fluid from said hydraulic motor and excess hydraulic fluid from said pressure tank.
11. The system as claimed in claim 7, wherein said piping system further comprises a plurality of one-way pressure relief or pressure difference control valves for confining the flow of said hydraulic fluid to the desired directions.
12. The system as claimed in claim 7, wherein said pressure tank and/or said hydraulic motor are fitted with pressure relief valves for draining excess fluid from the system.
13. The system as claimed in claim 7, wherein said pressure tank contains gas, the gas being compressed in high pressure for substantially rendering unruffled the pressure applied from said pressure tank to said hydraulic motor.
14. A system for conversion of wave energy substantially comprising any and all features of novelty as described, referred to, exemplified, illustrated or shown, hereinabove or in the accompanying drawings.



INTERNATIONAL SEARCH REPORT

International application No.
PCT/IL98/00118

A. CLASSIFICATION OF SUBJECT MATTER

IPC(6) : F03B 13/12

US CL : 405/76

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

U.S. : 405/76, 75, 77, 78

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X — Y	US 599,756 A (WRIGHT) 01 MARCH 1898 (01/03/98), SEE FIGURE 1, PAGE 2, LINES 29-134.	1 AND 7-14 ----- 2-5
Y	US 1,073,214 A (CARR) 16 SEPTEMBER 1913 (16/09/13), SEE PG 1, LINES 92-97.	2-5
A	FR 2,500,507 A1 (DEBRECZENY) 27 AUGUST 1982 (27/08/82), SEE ENTIRE DOCUMENT.	1
A	US 2,715,366 A (VARTIAINEN) 16 AUGUST 1955 (16/08/55), SEE ENTIRE DOCUMENT.	7-13

☐ Further documents are listed in the continuation of Box C. ☐ See patent family annex.

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